

Chapter 5

How We Value and Use Forests

How we value forests, and the importance that we attach to conserving and managing them depend, to a large extent, on our own personal philosophies and backgrounds. Our values, and those of others, are inextricably associated with the intended uses of forests.

People who live in and depend on forests are likely to think about the way they are used very differently from those who live in the cities of developed Western countries. We pointed out in chapter 1 that there are still people in the tropical forests of the Amazon, Indonesia, and Papua New Guinea who depend on the forests they live in for the materials to build their houses, for most of their food—obtained by hunting and gathering—and for plants with medicinal properties. The number of such people is now small, and there are probably few, if any, who have not been exposed to the modern world, its products, pressures, and way of life. The pressures on them and their environment are, in many cases, very strong. Logging and mining companies push into the forests, sometimes with the approval of national governments and sometimes illegally. Small groups of indigenous people who, in most cases, hold no formal title to their

land and who are unskilled in political negotiation, are generally helpless to resist encroachment and the destruction of their way of life. We can't speak for them but simply note that their rights must be considered: their continued existence provides a strong argument (among many) for the preservation of large areas of tropical forests.

Those who manage forested land for wood production are likely to take a fairly utilitarian attitude toward it: their objective is an economic return from the land. This is not to say that they don't value it from an aesthetic or ecological point of view, or that management for wood production necessarily results in serious reduction in other values, but it may do so. We discuss the management of forests used primarily as wood-producing systems in chapter 6, where we consider the economic factors that underlie management practices and decisions.

A great many people value forests mainly for their aesthetic values—their contribution to the beauty of scenery, or as places to walk and appreciate nature—or for ethical reasons, based on their appreciation of the ecological services provided by forests, from which everyone benefits. The attitudes of people with this point of view are likely to be different from those of production foresters, although there is no fundamental reason why the objectives of the two groups can't be reconciled.

Conservationists, hydrologists, and climatologists are concerned with the role and importance of forests in local, regional, and global ecosystems. They think in terms of the processes described and discussed in chapter 3, and the ecosystem services forests provide. These include the absorption of carbon dioxide (CO_2) and carbon storage, clean air, clean and reliable water supplies, and the conservation of biodiversity. The knowledge generated by those who study these matters is important for ensuring that the yields from forests managed for wood production are sustainable,¹ ideally, even under changing climatic and economic conditions.

Since we are forest ecologists, our perspective in relation to the use of forests is strongly influenced by our knowledge of the ecosystem services they provide. That value system underlies the following

discussion. However, we recognize the importance and economic value of forests as wood-producing entities, and we are not arguing that ecosystem services and ethical and environmental value systems are necessarily better than, or should outweigh, the conventional economic considerations that underlie wood production operations. Such judgments are, to a large extent, philosophical matters and outside the scope of this book: readers will have their own positions. We observe, however, that if unsustainable forest practices and policies are followed, societies suffer.

Ecosystem Services and Universal Values of Forests

The word *use* in the title of this chapter implies active utilization. But, besides the products derived from active utilization, forests provide ecosystem services that support the web of life and benefit humanity as a whole. Three are of particular importance: the reliable maintenance and supply of clean water; the absorption of CO₂ and storage of large amounts of carbon in forest biomass, and the maintenance of the biodiversity. All are essential for the long-term health and resilience of the world's plant and animal populations, and therefore for the health of human populations.

Reliable Supplies of Clean Water

The principles underlying the flow of water from catchments—the water yield—are contained in equation 1 in chapter 3, and some of the implications of clearing forests from these areas are discussed in general terms in that chapter. Obviously, the flow of water from a catchment depends not only on the vegetation cover (e.g., forest, grassland, agricultural crops), soil type, area, and topographic features, but also on the frequency, intensity, and physical nature of the precipitation. Vegetation cover is seldom homogenous, particularly in areas that have been developed for human occupation, so comparisons between watersheds are invariably difficult, but we can make some valid general statements.

Peak outflows usually occur during and after rain events large enough to generate maximum stream flow from runoff. For comparable sized catchments and amounts of precipitation, these will always be lower from one that is forested than from those where the vegetation is predominantly grassland or crops. (Of course if large areas are covered by houses and paved roads, almost all rainfall or melting snow will run off immediately.) The high runoff rates from cleared land are likely to produce soil erosion. This is always a problem in cropping systems, particularly those that leave the soil unprotected by vegetation for significant periods of each year. Rapid runoff causing erosion carries soil that causes dams to fill with silt. It also carries contaminants, such as pesticides, and nutrients that degrade water quality and can encourage algal growth in water storages. Forests will not stop floods resulting from exceptional precipitation, but their root systems hold the soil and provide insurance against washouts and landslides of the sort that occur frequently in high rainfall areas denuded of forest cover.

Base flow is the term used to describe longer-term rates of water supply from a drainage basin. Base flow is the result of lateral movement of water through saturated subsurface soil. It depends on the amount of water that has infiltrated into the soil, and on soil properties. Because infiltration rates are high, the proportion of the water in a given precipitation event that runs off across the surface of forest soils is generally small. As a result the amount of water stored in forest soils tends to be high, and base flows are maintained for long periods.

There is a great deal of research, reported in the technical literature, which indicates that, in general, the water yield of forested drainage basins is more stable than that from cropped or rangeland catchments. However, water yields are often lower from forested catchments because forests tend to transpire more than other vegetation types. Their canopies also intercept more water than smaller vegetation. This water is lost by evaporation. In general, water yield increases following reductions in vegetative cover. Research shows that thinning forests increases the water yield of catchments and

causes groundwater levels to rise. This is because thinning reduces the leaf area index (LAI; see chapter 3), so that both transpiration and interception of rain or snow by the canopy are reduced. In parts of Australia (and no doubt elsewhere), the removal of forests and woodlands has resulted in rises in groundwater levels, which has had the unwanted effect of bringing toward the surface salt stored deep in the soil. This leads to rising salinity levels in streams and the surface soil, and has adverse effects on crops in the affected areas.

The possible benefits of the higher water yields that may be obtained by thinning or removing forests, which civic authorities concerned with water supplies to cities might see as desirable, may be more than offset by possible losses in the stability of water yield, and by poor water quality. A study by the US National Research Council² on the hydrologic effects of forests showed that forests provide natural filtration and storage systems that process nearly two-thirds of the water supply in the United States and that healthy forest vegetation can benefit human water supplies by controlling water yield, peak flows, base flows, sediment levels, water chemistry, and quality. Forest cover in catchments can substantially reduce the need for treatment to treat water for domestic use, and thus significantly reduce the costs of supplying water.

A 2008 report from the UN Food and Agriculture Organization (FAO)³ supports many of the points we have made: forested watersheds provide high-quality water by minimizing erosion, reducing sediment movement into water bodies (dams and lakes), and by trapping and filtering other contaminants and pollutants.

Carbon Dioxide Absorption and Storage

The process of photosynthesis by which forest canopies absorb CO₂ was outlined in chapter 3, and some of the consequences of deforestation and land-use change were discussed in chapter 4 in relation to climate change. Since the absorption and storage of carbon (C) by forests is inarguably an important ecosystem service, we present, in table 5.1 data for the fluxes of C into forests, emis-

TABLE 5.1. (a) Carbon (C) fluxes and (b) storage in the world's forests
(a)

<i>Forest type</i>	<i>Boreal</i>	<i>Temperate</i>	<i>Tropical intact</i>	<i>Tropical regrowth</i>	<i>Tropical deforestation</i>	<i>Tropical land-use change</i>
Fluxes (Pg C yr ⁻¹)	0.5±0.08	0.72±0.08	1.18±0.41	1.64±0.52	-2.93±0.47	-1.29±0.70

(b)

<i>Forest component</i>	<i>Live biomass</i>	<i>Dead wood</i>	<i>Litter</i>	<i>Soil</i>
Stored C (Pg)	363±28	73±6	43±3	383±30

Note: 1 Pg = 10^{15} gm = 10^9 tons. Carbon in CO₂ is 27% of the total mass, so a ton of carbon is equivalent to 3.67 tons of CO₂ absorbed, emitted, or stored by forests, i.e., 1 unit C≈3.67 units CO₂.

sions from them, and the amounts stored in different forest types. Fluxes are positive values, and emissions, negative values. The uncertainties in the estimates are the values following the ± operator. Storage data describe the total amount of C stored globally in different components. The data in this table are derived from Pan et al. (2011). Carbon in CO₂ is 27 percent of the total mass, so a ton of carbon is equivalent to 3.67 tons of carbon dioxide absorbed, emitted, or stored by forests.

The data in table 5.1 indicate that, globally, forests absorb much more carbon than they emit. However, the very large negative fluxes, that is, C emissions, from tropical deforestation and tropical land-use changes, outweigh, by a wide margin, the absorption of carbon by those systems, illustrating the contribution that deforestation in the tropics makes to the accumulation of CO₂ in the earth's atmosphere (see also figure 4.2). It's also important to note that the amount of carbon stored in forest soils is slightly larger than the amount stored in live biomass. The authors of the paper from which these data were taken found that there is a fundamental difference between

tropical and boreal forests in their carbon storage patterns: tropical forests have 56 percent of carbon stored in biomass and 32 percent in soil, whereas boreal forests have only 20 percent in biomass and 60 percent in soil. The relatively small proportion of carbon stored by tropical forest soils is a result of the rapid decomposition and turnover of organic matter in those soils, while the high storage in boreal forest soils lends emphasis to the point made in chapter 4: the area supporting boreal forests contains a large proportion of the world's soil carbon. If the decomposition of this carbon is accelerated by rising temperatures, it will release enormous quantities of CO₂ into the atmosphere.

Biodiversity

Biodiversity refers to species richness: the range of plants and animals, which includes insects and microorganisms that exist in a specified geographical region. The word may also be applied to genetic diversity.

Biodiversity is central to ecosystem functioning. Healthy ecosystems contain a range of animal, bird, and insect species that fulfill various functions: predators and prey, pollinators and seed disseminators—some of which are species-specific, some general. Both live and dead organic matter is consumed and broken down by a multitude of organisms. A healthy ecosystem is dynamic; there is continual change and interaction among its components. Different plant species fill various niches in ecosystems by exploiting environmental resources (light, water, nutrients from the soil) in different ways, reacting differently to changing conditions. They are eaten by different insects and other animals, and seeds are disseminated by a range of mechanisms. Communities (ecosystems) with high biodiversity are far more resistant to serious damage by a disease, or suites of diseases, that may attack some species but to which others are resistant. They are also likely to contain species with a range of abilities to withstand changes in environmental conditions such as those likely to result from climate change. High biodiversity

usually ensures that ecosystems are both resistant to change, and resilient in the face of disturbances.

Genetic diversity means there is a wide range of genes within plant communities. In natural ecosystems there is genetic diversity within and among different species. In monocultures, if there are genetic differences between individuals within the population, some are likely to be resistant to attacks by insects, or to infection by disease organisms. This ensures that, when attacks or epidemics occur there will be survivors that can pass on their resistance to future generations. Clonal monocultures, where all individuals in the population have the same suite of genes, can be susceptible to devastating damage if attacked by a disease or insect species to which the genotype is susceptible. The genetic diversity in forests must be maintained to provide the genes needed as the basis for breeding programs to produce trees with desirable wood production properties, and with the ability to resist or recover from disease and insect attacks. The latter are likely to become more frequent and severe in future (see the report by Woods et al. [2010] on forest health and climate change discussed in chapter 4). The genetic resources of forests, particularly tropical rainforests, also provide a valuable reservoir that humans may need to draw on, for example, for the genes we need to restore the resilience of our agricultural systems or to provide the basis for novel pharmaceutical drugs. Humanity's current dependence on the productivity of vast monocultural systems, in turn dependent on massive chemical inputs, is dangerous and inherently unstable.

Some plant species have medicinal properties: quinine, the first chemical (we would now call it a pharmaceutical) to be effective in the treatment of malaria, comes from the forests of South America. People indigenous to the tropical rainforests are known to have identified thousands of plant species that have biological effects—medicinal, psychological, or recreational—on humans. Shamans have been experimenting with various combinations and dosages for generations. Rainforest plants are the source of many of the drugs, both pharmaceutical and recreational, used in the developed world.

Since there are still thousands of plants that have not been examined for possible medicinal properties, it's safe to assume that there will be, among them, a great many that provide chemical compounds with medicinal value. The US National Cancer Institute estimates that 70 percent of the plants with anticancer properties are found only in tropical rainforests (see Butler 2012; also, on the *National Geographic* website, "Rain Forest: Incubators for Life"⁴).

The Uses of Forests

Humans have, from time immemorial, lived in and used forests, and we have already mentioned that there are still groups of people for whom the tropical forests provide everything they need in their lives. We also noted in chapter 1 that in the developed countries—northern Europe and North America, but also Australia—people use the forests for recreation: for hiking, camping, and hunting and, particularly in the Scandinavian countries, for berry and mushroom collecting. The social importance of these activities varies from place to place. Our concern, in this chapter, is with the major direct use of forests for wood production, a use and activity that has been important for thousands of years. We discuss the modern situation.

Harvested Wood and Its Uses

Wood products can, for convenience, be considered in three major categories: pulpwood, sawn timber, and wood for fuel.

PULPWOOD

Pulpwood is used predominantly to make paper, cardboard, and packaging materials. Despite the decline of newspapers as the modern world moves toward electronic communications, there is still a vast market for newsprint. Consumption of newsprint is declining in the Western countries, but in China and India there are still hundreds of high-circulation newspapers, consuming thousands of tons

of newsprint daily. Add to that magazines, advertising material (including vast quantities of “junk mail”), wallpaper, wrapping paper, office, or copy, paper, and toilet tissue of various types and it seems clear that the markets for pulpwood are likely to remain strong, at least for the foreseeable future.

Stands harvested for pulpwood are invariably *clearcut* (also referred to as *clear-felling*). The trees are cut, debarked in the field or at the mill, and pulverized either mechanically or with chemicals to separate the cellulose from the lignin fibers. The chemical process is known as the *Kraft process*. It’s the more common one in modern pulp and paper production, producing pulp that can be used to make higher-quality papers than the mechanical process. The wood from different tree species has different properties in relation to pulp for papermaking, the most important of which are differences in length of the wood fibers and in wood density⁵—the number of fibers per unit mass. In general, both dense hardwoods, such as oak, beech, and eucalyptus, and lighter ones, such as poplar and willow, have shorter fibers than the softwoods, which include pine, spruce, and fir. The pulp from different species can be mixed to give the papermakers more control over the quality of paper they produce.

Until about the 1990s, most pulpwood came from naturally or artificially regenerated forests, that is, forests that had been previously logged and allowed to regrow, in Canada, the United States, and northern Europe, with a significant proportion from the softwood boreal forests. In recent years, the proportion of pulpwood from plantations has been increasing steadily, and the bulk of pulp production now comes from plantations. In fact, a 2007 FAO report⁶ shows that over 50 percent of pulpwood traded on international markets now comes from eucalypt plantations. Much of the expansion in plantations is in tropical areas, particularly Latin America and the Caribbean, where the forest products industry is largely based on plantations. Nevertheless, Europe, including Russia, is still the largest paper products exporting area. The extensive softwood plantations in Chile, New Zealand, and South Africa provide both pulpwood

and sawn timber products. The industries in Chile and New Zealand, and the wood chip industry in Australia, are strongly export-based, but because these are small countries their impact on the overall world markets is also small.

It's interesting to note from the FAO report (2007) that paper and cardboard consumption—reflecting pulpwood consumption—has fallen slightly in North America, reflecting the global financial downturn in 2008, but it is rising steadily in Asia, reflecting the rapidly expanding Chinese economy.

WOOD FOR FUEL

For much of human history wood was virtually the only fuel for cooking, heating, and processes such as smelting (see comment in chapter 1). The Industrial Revolution of the nineteenth century, originating in Britain, was driven by steam but would not have been possible without coal, which became the major fuel source. Coal was also used as domestic fuel, and the smoke produced by countless coal-burning stoves and heaters was largely responsible for the appalling smogs that were characteristic of industrial Britain in the nineteenth and early twentieth centuries. But although wood had been supplanted as the major industrial fuel, it remained important in most parts of the world, not least in the United States where, although coal provided the energy for most industry in the nineteenth century, it was wood that fired the boilers of the iconic steamboats. And, as the railways pushed across the continent, their boilers were also, initially, wood fired. The demand for wood by the steamboats and railways resulted in the destruction of huge areas of forest, particularly along the Mississippi, where the consequent bank erosion contributed to the increasing silt load of the river system.

In today's world, wood remains an enormously important fuel, with the advantage that it is a renewable source of energy. The FAO report (2007) shows that, of the approximately 3.5 billion cubic meters of timber harvested in the world in 2007, slightly more than half was used for fuel.⁷ Much of this is in developing

countries with large populations of poor people; the rural poor in particular have no options but to use firewood for cooking. Their need to collect wood for this purpose involves endless, tedious labor, the burden of which falls primarily on women. It also results in denudation of woodlands and, in some cases, forests. Another little-recognized effect of firewood collection is the removal of all litter from plantations, short-circuiting the recycling process and contributing to the progressive loss of nutrients from the system. Soil structure also tends to degenerate as a result of the progressive loss of organic matter.

These problems—fuelwood availability, soil degradation, and nutrient depletion—can be solved by establishing plantations specifically for the purpose of providing domestic fuel. Australian researchers have been active in this area, investigating the burning properties of wood from various species. The ubiquitous eucalypts are now widely grown specifically for fuelwood, but some other species, notably *Acacia mangium* have been shown to serve the purpose well.

In the developed world, technological developments have made wood a far more efficient fuel in terms of the energy released by combustion. This is achieved by producing low moisture-content pellets and briquettes, burnt in customized stoves and boilers, where the combustion process is usually accelerated by fans blowing air into the combustion compartment. The technology has been developed to the point that wood pellets are now used to provide the heating, ducted from central burners, for apartment blocks. This use of these wood products has an energy cost, in producing the pellets or briquettes, but major advantages in ease of transport (the products are much lighter than “raw” wood), energy release, and reduced pollution because of the clean combustion. Pellets and briquettes can be produced from wood pulp or the waste left after logging operations; there are now a number of mobile pellet-producing machines available, and no doubt there will be continued development in this area.

There is research, in a number of places, on the production of *ethanol* from wood. Ethanol is the form of alcohol used to supplement

petroleum fuels. It's currently produced mainly from sugar cane (Brazil is the leader in that) and from corn, in the United States. Production from corn distorts the market for the grain as a food source and, in a time when food production looms as an increasingly important problem for the world's rapidly increasing human population, it is, arguably, a serious misuse of resources. The ethanol produced from corn is called starch ethanol. Starch is a relatively simple carbohydrate and the process of converting starch into sugar and then fermenting that to produce ethanol is straightforward. Ethanol from wood is called cellulosic ethanol. *Cellulose* is far more complex than starch, and the ethanol production process is more complicated and currently too expensive for widespread use.

There are claims that economically feasible techniques of ethanol production from wood are being developed. If true, we may expect that, in the near future, corn will be replaced as the feedstock for the process by low-quality pulpwood and wood waste from forestry operations. Such a development will be particularly important in Europe, which has neither the corn production potential nor the fossil fuel reserves available to the United States. However, as with most technologies, there is a potential downside: if the debris left by forest operations was to be removed consistently, there would be progressive reductions in the organic matter content of forest soils, leading to long-term deleterious effects on fertility and soil stability. The likelihood of this happening would be increased if tree stumps and root boles were removed.

Charcoal—essentially carbonized wood—has a long history. In fact much of the wood used as fuel in processes such as smelting, before coal displaced it, was in the form of charcoal. There are various methods of making it: the basic process is a controlled, slow, cold burn that dries and carbonizes the wood. Traditionally, in many countries, including much of Europe, the charcoal burners were people who often lived isolated lives in the forests, exercising their inherited skills and experience to produce a valuable fuel. Charcoal remains an important fuel today. Inevitably, there are industrial methods of making it.

SAWN AND PROCESSED TIMBER

Sawn timber comes from trees that have good form, that is, they are large and straight enough to provide good quality planks and boards. For hundreds of years, in many places throughout the world, houses were built entirely from timber, and this is still the case in many places. Even where houses are built mainly from brick, many of them contain internal walls based on timber framing, and roof trusses are generally timber. House construction remains one of the largest consumers of solid timber; periods of economic downturn and slow house construction have direct effects on the markets of solid timber.

There are now a number of substitutes for timber from large trees. Small wood can be debarked, shredded, and glued to produce various products such as particle, chip, wafer, fiber, or strand board. These can be made to any required dimensions; they are workable, like wood, and can be produced with great structural strength. Such products provide another alternative use for smaller wood pieces.

The other major use for sawn wood is furniture manufacture. China is currently the world's largest exporter of wood furniture, using wood produced domestically and imported. China is also a major importer of tropical hardwoods. Because the market it provides for this timber is largely unregulated, it is indirectly responsible for much of the illegal logging that is contributing to the destruction of the forests of Southeast Asia.

In the past, when trees were felled using axes and the timber taken out of the forests by horse- or ox-drawn wheeled vehicles, so-called selective logging was the normal practice. Generally, relatively few of the trees in a stand were removed, leaving the others to take advantage of the gaps created and become larger, perhaps to be logged in another cycle if they were of high enough quality. Nowadays, the advent of highly effective chainsaws and powerful, heavy machinery has made it possible to cut trees rapidly and move large quantities of timber quickly. Clearcutting

has become the normal practice. Logging roads are driven into the forests by bulldozers, and everything in a stand is cut down and delimbed; bunched and loaded by grapple hooks, cranes, or forklifts; then trucked to a mill or exported. In some operations in old forests where most of the trees are large, all the marketable trees will be harvested and the tops and branches left as debris on the site. In other cases, the large trees are taken to sawmills, and the smaller are converted to wood chips, which then go for pulp. We consider the implications of clearcutting natural forests, and the management of logging debris, in chapter 6.

In Australia there have been long-running controversies about the logging of old-growth forests. Most of the state forest services were established in the late nineteenth and early twentieth centuries, with the primary objective of ensuring that supplies of timber were adequate to meet the requirements of the developing economy. Management to conserve flora and fauna was always a secondary objective which, in most of the states, was later handed to departments of wildlife and conservation. Since there was virtually no *silviculture* involved, the practice was inexpensive, and the foresters argued that it was sustainable in terms of wood yield—the primary criterion by which the operations were judged. However, there was growing unease among increasing numbers of people in the wider community about the ecological consequences of clearcutting native forests, particularly mature, multistoried (so-called old-growth) forests.

The essence of the argument runs like this: the foresters asserted that the plant communities that emerge from the seedbeds created by clearcutting and burning the *slash* are new and vigorous versions of the old communities. This is difficult to support with empirical evidence: there are likely to be species changes, and if the clearcut is planned as the precursor of another logging operation in, say, forty to eighty years (a commonly cited rotation length for saw log production), then by definition the forest is not the same, nor will it store the amount of carbon present in the original stand. The operation might be sustainable

in terms of wood yield, but it is not sustainable in terms of equity between generations: subsequent generations will not be able to enjoy the aesthetic benefits and ecosystem services of great old trees, and some of the more specialized plants and animals that reside in such habitats will not survive.

There were economic as well as ideological reasons for the controversy. Because of the history of forestry in Australia, the logging companies, throughout the forested areas, were equipped to deal with large trees, as was the sawmilling industry. In response to pressure to move their operations into plantations, the loggers and sawmill owners claimed, with justification, that there was not enough wood available from plantations—certainly not enough of saw-log size and quality—to support the industry and provide the country's sawn timber requirements. It was also claimed that relatively young, plantation-grown wood was not suitable for sawmilling (the technical problems in this respect have now been largely overcome). Furthermore, sawmills would have to retool to deal with smaller trees. Unfortunately, the resistance within the industry to change its practices translated into a reluctance to invest in the establishment and management of plantations, so that the transition of the forestry industries from native forests to plantations has been slow. However, the areas under plantations are increasing, and the wider community and ecological considerations have prevailed, if not yet entirely.

The controversy (which has many more complex ramifications than we have been able to outline here) encapsulates the difficulty of changing entrenched positions and adapting to the needs of a rapidly changing world. It has now been largely resolved, but the political compromises involved in the resolution mean that mature native forests are still being logged. There was a similar argument in New Zealand where, from the time of colonial settlement, there was massive forest clearance for agriculture as well as logging for sawn timber. It was resolved by heavy investment in plantations and government decrees that stopped all logging in native forests.

Abuses of Forests

If we accept that the preservation of remaining forests should be an important objective for any country, for reasons relating to the ecosystem services they provide and the values discussed in the previous sections, then we should accept the assertion that any human action that directly results in the destruction or degradation of forests can be called abuse. This proposition may seem to run counter to the requirements of increasing numbers of humans for land for agriculture and living space, both of which result in forest destruction. It would be inappropriate in this book to try to explore the implications and arguments in particular situations, but we note, in passing, that the solution to the impending problems of feeding the world's human populations should not lie in trying to clear more tropical forests for agriculture. An analysis by Foley et al. (2011) led to the conclusion that tremendous progress in meeting the world's food requirements could be made by halting agricultural expansion, closing "yield gaps" on underperforming lands, increasing cropping efficiency, shifting toward more plant-based diets, and reducing waste. Together, these strategies could double food production while greatly reducing the environmental impacts of agriculture.

Urban Development

Most of the abuse of forests is in the tropics, but growing populations exert pressure everywhere. In California, for example, although society there is very aware of environmental issues, the demands for a pleasant lifestyle in beautiful surroundings have led to houses being built in forested areas. These bring with them access roads and the disintegration of forests into separated subunits within and between which the integrity of the forests is compromised. Urban development of this sort also brings with it pressure on authorities to prevent fires, resulting in fuel buildups and serious problems during drought periods in hot summers. The damaging fires experienced in California in recent years are largely a consequence of this sort of

development, exacerbated by the droughts associated with climate change and the excessive accumulation of fuel.

Australia has the same problem. We noted earlier that the fires in the state of Victoria in 2010 destroyed several small towns and killed 170 people. Much of the damage was directly attributable to the fact that the towns were deliberately built in the forests—they were lifestyle choice towns; people wanted the sylvan environment, the trees and the wildlife, beauty and peace. All good, except that they also demanded that the forests should be as undisturbed as possible—there were even regulations against collecting dead wood for firewood. So when extreme conditions happened—dry, very high temperatures ($>40^{\circ}\text{C}$, i.e. $>104^{\circ}\text{F}$) and strong winds—ignition occurred from power lines brought down by wind, and the result was a massive firestorm. Such high-intensity fires are destructive not only to humans but also to the forests themselves, where the lack of fuel management led to accumulations of highly combustible material, and the fires killed trees that would have survived moderate burns.

Tropical Forest Destruction

Much of the extensive logging that takes place in tropical rainforests is illegal, particularly in Indonesia, Laos, Cambodia, Thailand, Papua New Guinea, and Brazil (although that country is making serious efforts to control it). It is driven by the market for tropical hardwoods in China and Korea.

Papua New Guinea's (PNG) forests are the third largest, and some of the most diverse, on earth. However, the World Bank estimates that over 60 percent of PNG's original forests have already been destroyed by logging and industrial agriculture, and that 70 percent of logging in PNG is illegal. According to the environmental organization Greenpeace,⁸ illegal logging costs timber-producing countries between US\$10 and US\$15 billion per year in lost revenue. This accounts for over a tenth of the worldwide timber trade, estimated to be worth more than US\$150

billion a year. But Greenpeace also points out that importing countries must share the blame for the devastation. China, with its current focus on development and economic growth, is unlikely to be interested in doing so.

In Asia the pressures on forests are from burgeoning human populations, as well as from ruthless commercial logging subject to very little control in most countries of the region, and from clearing for crops such as palm oil. Such clearance not only destroys the forest (which is the intention when plantations are to be established) but where the slash (foliage, branches, tree tops) left on the ground is burned, it creates serious smoke pollution over the region. At the time of this writing (mid-2013), the blanket of smoke from illegal land clearance in Indonesia, drifting over Malaysia and Singapore, is dense enough to constitute a health hazard and cause international protest. And this is a regular occurrence.

The palm oil industry in Indonesia and Malaysia is developing rapidly. In 2012 the Indonesian government designated about 35 million hectares of already-logged forest for farmland or exotic tree plantations. The sequence is this: the forests are logged and damaged, then said to be too badly degraded to be worth preserving, so they are made available for “development.” There is a website⁹ where the ecological implications of the oil palm plantations are documented. They include destruction of orangutan populations, which are in danger of extinction; the destruction of ecosystem values and services; and a range of adverse effects on indigenous human populations. Many oil palm plantations are being established in low-lying areas that were rainforests, where deep peat has accumulated in the swampy conditions. Forest clearance and burning lead to the decomposition of this peat and massive emissions of CO₂.

We have already commented on the dangers and short-term benefits of farming on land that was tropical forest: lacking the organic matter additions from litterfall and rotting material, tropical soils become depauperate within a few years, and will not produce worthwhile crops. Oil palm plantations have similar effects. They

do not provide significant protection against runoff and, within ten to fifteen years, the soil nutrients have been oxidized, volatilized, or leached out.

There is extensive land clearance for agriculture in the Amazon, as well as damage to forests caused by mining and river damming. Damage to and exploitation of the forests there are driven by ever-growing human populations and the ever-growing demand in international markets for hardwood timber. In South America, roads are being pushed into the forests and the rural poor move in along those roads; according to Bill Laurance,¹⁰ 95 percent of all deforestation in the Amazon occurs within 10 km of roads. Peasants move in along these roads and carry out slash and burn, shifting agriculture. These people can't be condemned for their actions, even though those actions are frequently illegal. They usually have very limited opportunities to make a decent living, but their agricultural practices destroy the forests. In Africa, too, the greatest pressures on the tropical forests come from expanding populations and constant clearance for agriculture. We have provided some additional comments on the reasons for forest destruction in the humid tropics in chapter 7.

Summary

The values placed on forests by humans vary. Those who live in forests and depend on them do not see them in the same way as those who live in developed countries, who may value forests for aesthetic reasons. The livelihood of the more forest-dependent people is under threat from logging and clearing forests for agriculture (which includes plantations).

Forests provide ecosystem services of universal value. These include the absorption and storage of carbon dioxide, reliable supplies of clean water, and biodiversity in the flora and fauna populations. The value of wood products is more easily appreciated by most people. Logging practices to obtain these products vary from careful selective logging to clearfelling (clearcutting), which

is now the normal procedure in many places. Wood is used for pulpwood, sawn timber products for building and furniture making, and for fuel. Wood used for fuel may be burned directly, or it may be converted into charcoal or wood pellets and briquettes to feed fires. The use of wood as a major source of fuel on railways and riverboats was a significant factor in the destruction of large areas of forest in the United States. It is likely that ethanol production from wood will become economically feasible in the near future.

Urban development, particularly in the western United States and in Australia, is steadily expanding into forested areas. This causes fragmentation and, because fuel builds up in forests around urban developments, fire management is difficult. When fires occur they are damaging and dangerous. Large areas of temperate forests are being destroyed for urban development in western North America as well as in smaller areas in Australia. Even larger areas of tropical forests are lost to clearing and burning in Indonesia and other Southeast Asian countries, as well as in the Amazon basin.